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# RELATION OF THE CHARACTER OF THE ENDOSPERM TO THE SUSCEPTIBILITY OF DENT CORN TO ROOT ROTTING.

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## EAR CLASSIFICATION BASED ON STARCHINESS.

Early in the course of investigations of the root, stalk, and ear rots of corn, differences were observed in the amount of starch in the various ears from which kernels were being germinated to determine the extent and character of seed-ear infections. These differences were noticeable not only among different varieties, but often equally so among the individual strains within a single variety.

It seemed important to determine what physical characters of the ear or kernel, if any, might be used in recognizing and eliminating infected seed ears. Obviously, such a procedure would be valuable in reducing the necessity for a detailed germination test of each ear.

The ears were classified on the basis of the endosperm. The starchy endosperm appears opaque when the kernel is held up to the light, but the portion containing horny endosperm is more or less translucent. Six degrees or types of starchiness were recognized and

designated as types A to F, inclusive (Pl. I). Where the starch zones of the crowns and tips of the kernel were completely united and the kernel was entirely opaque to transmitted light, it was designated as type A, or starchy. Kernels of which three-fourths of the endosperm was starchy were designated as type B. Kernels in which half of the endosperm was starchy were classed as type C, and those in which about one-fourth of the endosperm was starchy represent type D. Kernels showing only a narrow band of starch at the crown were designated as horny, or type E, and a few strains in which practically all of the endosperm was horny were designated as very horny, or type F. These types are shown in Plate I.

With this classification it was easy to separate the character of starchiness from that of indentation, with which it has been too frequently confused. Starchiness is characteristic of chaffy, immature ears, but is not necessarily associated with normally matured ears of rough indentation. Ear types commonly encountered are illustrated in Plate II.

Most of the ears studied fell within the range of types C, D, and E. Some strains averaged "C" in composition, and some northern Indiana strains of Ninety-Day corn averaged "F" in composition, or very horny. The larger, later maturing strains grown in the southern part of the State seemed to show some tendency to be more starchy than those grown in the northern part.

## RELATION OF ENDOSPERM CHARACTER AND EAR INFECTION.

The results of a study of the relation of ear composition to ear infection are shown in Table 1. This study was made upon representative ears supplied to this office for germination and field experiments during 1918 and 1919 by a number of the more prominent seed-corn growers of Indiana. On the basis of character of endosperm, the ears in each sample were separated into the two classes, starchy and horny, the dividing line being placed arbitrarily between types D and E. In studying the germination record of these ears, all ears were considered infected the kernels of which were characterized by growths of *Fusarium* spp., *Diplodia zeae*, or *Penicillium* spp. when accompanied by disorganized tissue surrounding the scutellum in each of duplicate germination tests made upon the limestone-base table germinator, as described by Hoffer and Holbert.[1]

[1] Hoffer, George N., and Holbert, J. R. Selection of disease-free seed corn. Ind. Agr. Exp. Sta. Bul. 224, 16 p., 20 fig., 1918.

TABLE 1.—*Infection by rot-producing organisms in starchy and in horny ears of several varieties of dent corn obtained from different parts of Indiana during 1918 and 1919.*

| Source of sample (Indiana). | Variety. | Average character. | Number of ears studied. | | | Infected ears (per cent). | |
|---|---|---|---|---|---|---|---|
| | | | Total. | Starchy. | Horny. | Starchy. | Horny. |
| Woodburn | Champion | F | 100 | 42 | 58 | 6.17 | 4.45 |
| Valparaiso | Ninety-Day | F | 100 | 24 | 76 | 58.33 | 43.24 |
| Fort Wayne | Early Yellow Dent | D | 100 | 40 | 60 | 57.89 | 17.59 |
| Rensselaer | Silvermine | E | 100 | 44 | 56 | 50.00 | 33.33 |
| La Fontaine | Reid Yellow Dent | E | 150 | 42 | 108 | 50.00 | 28.57 |
| Noblesville | do | E | 100 | 22 | 78 | 20.00 | 16.50 |
| Forest | do | E | 100 | 15 | 85 | 42.86 | 35.00 |
| Battle Ground | do | E | 100 | 24 | 76 | 50.00 | 23.08 |
| Sullivan | do | E | 100 | 37 | 63 | 43.75 | 37.04 |
| Pennville | do | D | 100 | 59 | 41 | 46.20 | 38.90 |
| Delphi | do | D | 100 | 34 | 66 | 76.92 | 41.67 |
| Fort Branch | do | D | 150 | 52 | 98 | 68.40 | 47.20 |
| New Richmond | do | C | 200 | 168 | 32 | 70.33 | 35.29 |
| Shelbyville | Johnson County White | E | 100 | 53 | 47 | 66.67 | 58.33 |
| Do | do | D | 400 | 304 | 96 | 55.27 | 41.67 |
| Hope | do | D | 100 | 54 | 46 | 51.56 | 34.78 |
| Total | | | 2,100 | 1,014 | 1,086 | | |
| Average | | | | 63 | 68 | 50.90 | 33.54 |

In every case the ears of the starchy class were characterized by a larger percentage of infections. This was especially noticeable in those strains which averaged a half (C) or a quarter (D) starchy. A very horny sample from Woodburn, Ind., carried a very low amount of ear infection. In this sample the differences between the horny and starchy groups were practically negligible. The most extreme difference occurred in a lot of starchy ears of Reid Yellow Dent from New Richmond, Ind. In this lot 70.33 per cent of the starchy ears were infected, compared with only 35.04 per cent of the horny ears. In general, such extreme variations have not been encountered. When all the samples subjected to this germination test, totaling 2,100 ears, are considered together, practically equal numbers of horny and of starchy ears are represented. The average proportion of infection in the horny group was 33.5 per cent and that in the starchy group 50.9 per cent, representing 17.4 per cent fewer infected ears in the horny group.

These data indicate that progress may be made in securing better seed ears by selecting those ears within the strain which have the more horny composition.

Though these data concerning ear infections of different varieties are meager, it is evident from the variations encountered among the nine separate strains of Reid Yellow Dent under comparison that as great variations in the character of the endosperm may occur among strains as among distinct varieties. The field performance of these strains indicates further that just as large variations in starchiness may occur among strains within a variety which require the same length of growing season.

With increased starchiness a number of factors operate toward increasing the number of ear infections. Immature seed ears are characterized by starchiness. Some of the starchy ears may come from the normally late-maturing strains, in which case the ear is exposed to weather conditions more favorable for infection by the root-rotting organisms during the period of ripening. Because of their high moisture content, such immature ears afford a good medium, even after harvest, for the development of these organisms when introduced from external sources. It has already been observed, however, that larger percentages of ear infection occur in the starchy groups of seed ears from strains with practically the same length of growing season. Field observations indicate that such seed ears are obtained from stalks suffering from an unbalanced food supply. Perhaps the main contributing factor is a root-rotted condition of the parent stalk itself. These factors merely furnish additional argument in favor of the practice of selecting seed ears from the stalk in the field.

## RELATION OF KERNEL STARCHINESS TO PATHOLOGICAL PERFORMANCE.

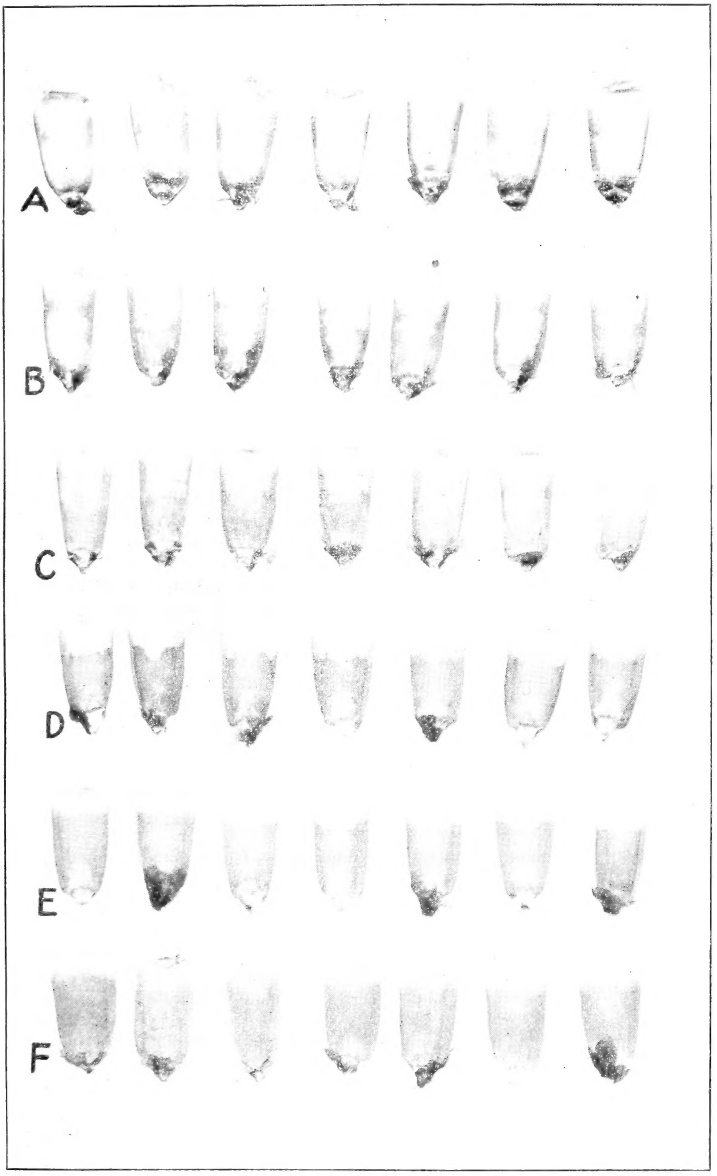
As starchy seed ears are more frequently infected with root-rot organisms than the more horny ears, it has seemed important to determine the relation of kernel starchiness to pathological performance in the field. Decreased stands and yields follow the planting of kernels from infected seed ears, as has been determined by the writer and by Duddleson and Hoffer[2] (unpublished data) and previously reported in the course of these investigations by Hoffer and Holbert.[3]

Because of the larger proportion of infections in the starchy seed ears, the planting of seed from these two groups without regard to the germination records would be expected to show superior yields from the more horny seed. In the study of the field effects of ear infection during the seasons of 1918, 1919, and 1920, approximately equal numbers of infected and of disease-free ears from the horny and the starchy groups were used in ear-to-row experiments. All rows were 75 hills in length. Only ears giving 100 per cent germination in the laboratory were used for seed.

The data from these plats have been summarized in Table 2 on the basis of starchiness of kernels. In this table the field performance of the horny groups of ears in each experiment has been taken as 100 per cent. The figures represent the percentage of decrease incurred through the use of the starchy seed ears. In all but one

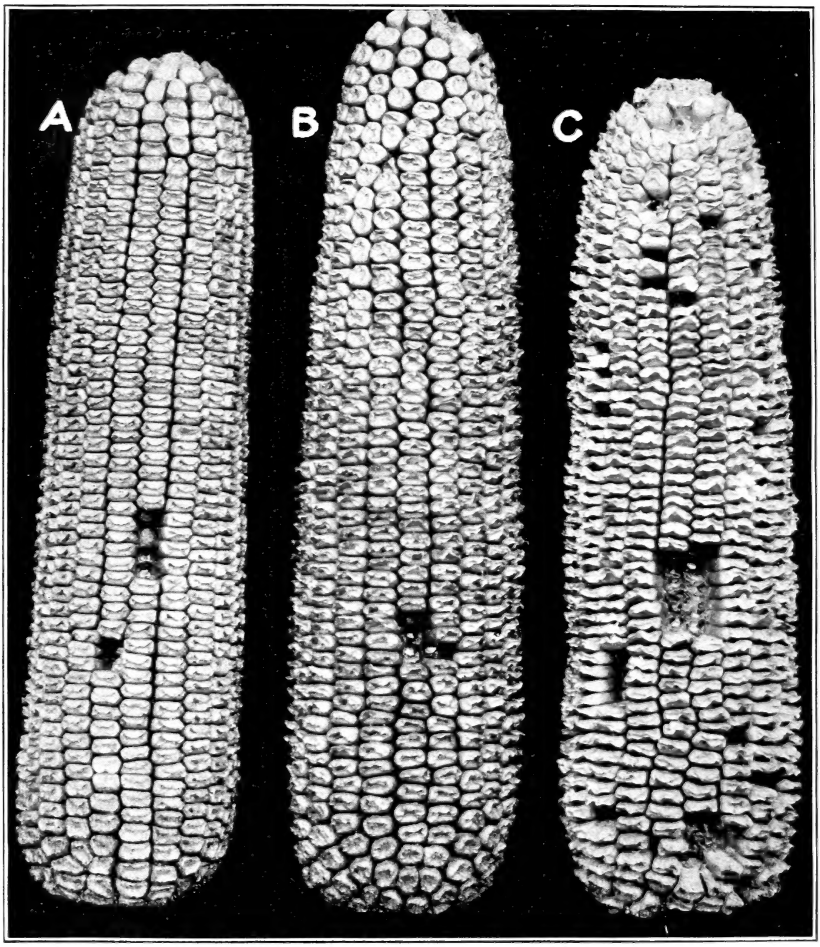
[2] Duddleson, B. H., and Hoffer, G. N. The improved rag-doll germinator for the elimination of diseased seed corn. (Manuscript.)

[3] Op cit.




KERNEL TYPES OF CORN SHOWING GRADATIONS OF STARCHINESS.

*A*, Starchy; *B*, three-fourths starchy; *C*, half starchy; *D*, one-fourth starchy; *E*, horny; *F*, very horny type.




COMMON TYPES OF SEED EARS OF REID YELLOW DENT CORN, ILLUSTRATING THE RELATION OF INDENTATION AND STARCHINESS.

*A*, Normally matured, smoothly indented, horny ear; *B*, normally matured, roughly indented, horny ear; *C*, chaffy, immature, roughly indented, extremely starchy ear.

experiment, that at Woodburn, Ind., the horny ears produced the higher initial stand in the field. This difference in stand was maintained throughout the growing season, as shown by the figures for initial stand compared with those for final stand, taken just previous to harvesting. This inferiority in stand was reflected in the decreased yield of the starchy group. Results due to differences in stand were eliminated by correcting the yields of both groups to perfect stand for each experiment. In this manner the actual superiority of the horny seed ears becomes apparent. Thus, while the average difference in final stand in the 11 experiments was 2.78 per cent less for the starchy ears, this was accompanied by an average reduction in actual yield of 5.57 per cent. Upon correcting both groups to perfect stand, the average decrease in yield incurred through the use of starchy seed ears amounted to 4.2 per cent.

TABLE 2.—*Actual and corrected yields from starchy and from horny ears of dent corn in ear-to-row tests in Indiana in 1918, 1919, and 1920.*

| Location of plat (Indiana). | Number of ears used in each plat. | | | Decrease resulting from the use of starchy seed (per cent). | | | |
|---|---|---|---|---|---|---|---|
| | | | | Stand. | | Yield. | |
| | Total. | Starchy. | Horny. | Initial. | Final. | Actual. | Corrected to perfect stand. |
| Fort Wayne | 45 | 19 | 26 | 4.12 | 4.26 | 6.51 | 5.17 |
| Woodburn | 48 | 20 | 28 | (1) | 3.04 | 1.26 | 4.44 |
| Valparaiso | 46 | 11 | 35 | 4.30 | 5.48 | 8.21 | 4.83 |
| Noblesville | 50 | 11 | 39 | (1) | 1.47 | .93 | .89 |
| Pennville | 44 | 26 | 18 | (1) | .78 | 7.24 | 6.96 |
| Delphi | 50 | 17 | 33 | (1) | 1.73 | 9.21 | 3.57 |
| Fort Branch | 37 | 21 | 16 | 9.86 | 6.21 | 8.38 | 4.69 |
| New Richmond | 80 | 62 | 18 | (1) | .54 | 6.40 | 6.21 |
| Shelbyville | 45 | 35 | 10 | 4.64 | 5.05 | 6.50 | 4.05 |
| Cannelton | 20 | 5 | 15 | 1.60 | 1.34 | 2.39 | 1.88 |
| Rockport | 49 | 21 | 27 | (1) | .72 | 4.20 | 3.47 |
| Average decrease from the use of starchy ears | | | | | 2.78 | 5.57 | 4.20 |

[1] Initial stand records were not made in these experiments.

## SUSCEPTIBILITY OF DISEASE-FREE SEED EARS.

To determine the relative susceptibility to root rotting of the horny and starchy groups of seed, a field experiment was outlined in 1920 in which alternate rows were planted with kernels from selected horny and starchy disease-free ears of a single strain of Reid Yellow Dent. In the horny group most of the ears were classified as type F. In the starchy group no ears less than half starchy (type C) were employed. This experiment was conducted at Bedford, Ind., and was duplicated in a fertilizer plat at Linden, Ind. The plats were each 1 acre in size. Owing to evident errors introduced by marked soil inequalities, the taking of notes was dis-

continued on the Linden plat after recording the initial stand. The data at Bedford were taken throughout the growing season and include the harvest results.

A complete analysis of the field results obtained in this experiment is given in Table 3. At Bedford the average reduction in initial stand due to planting starchy ears was 4.26 per cent. The reduction at Linden amounted to 10.21 per cent. The weather conditions following the planting of this plat were very unfavorable for germination. Thus, it appears that starchy ears are especially unsatisfactory for seed in districts where weather conditions are likely to make it difficult to secure a good stand. As in the earlier experiments, the difference in stand was maintained throughout the growing season. As the difference between the initial and the final stands is made up of losses sustained through blighting, and principally through seedling blight, the results indicate that the susceptibility of the two groups to such blighting is equal.

TABLE 3.—*Yields from starchy and from horny disease-free seed of a strain of Reid Yellow Dent corn, planted in alternate rows at Bedford, Ind., in 1920.*

| Group. | Number of ears used. | Agronomic data (per cent). | | | | | | | | | | Yield per acre (bushels). | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Stand. | | Plant vigor. | | | Stalk condition. | | | Quality of ears. | | | |
| | | Initial. | Final. | Vigorous. | Semivigorous. | Weak. | Barren. | Leaning. | Down. | Good. | Nubbins. | Actual. | Corrected to perfect stand. |
| Horny | 19 | 86.9 | 83.7 | 61.8 | 17.9 | 3.7 | 7.2 | 44.5 | 1.7 | 46.7 | 29.5 | 38.43 | 40.7 |
| Starchy | 17 | 83.2 | 79.6 | 51.6 | 20.1 | 7.3 | 11.4 | 45.9 | 2.6 | 41.0 | 27.4 | 32.09 | 35.0 |
| Difference: | | | | | | | | | | | | | |
| Actual | ..... | 3.7 | 4.1 | 10.2 | − 2.2 | 3.6 | 4.2 | 1.4 | .9 | 5.7 | −2.1 | 6.34 | 5.7 |
| In favor of horny ears | ..... | 4.26 | 4.84 | 16.5 | −12.6 | 97.3 | 58.3 | 3.14 | 53.0 | 12.2 | −7.2 | 16.41 | 14.0 |

Records were taken on the relative vigor of early growth 40 days after the date of planting. At this time the plants averaged 24 inches in height. They were classified arbitrarily as vigorous, semivigorous, or weak, and records for the entire plat were taken on the same day by one person, thus insuring the maintenance of the same standard of classification. Rows from the horny seed contained larger numbers of strong plants and markedly smaller numbers of weak plants than those from starchy ears. These results are in agreement with the studies reported by Hughes,[4] in which he found that horny kernels gave a more rapid early growth than starchy ones. His data covered a period of only 20 days, however, at the end of which

[4] Hughes, H. D. The germination test of seed corn. Iowa Agr. Exp. Sta. Bul. 135, pp. 305–379, 22 fig., 1913.

time the seedlings from the starchy kernels had practically caught up with the others. His opinion that the advantage ordinarily obtained by rapid early growth is not retained throughout the season is not borne out by these Indiana experiments. In the Bedford experiment the advantage of stronger early growth is reflected at harvest time in the higher proportion of good ears and the lower percentage of barren stalks.

Leaning and down stalks have been considered valuable external indications of a root-rotted condition. Just prior to harvesting, a heavy windstorm lodged about 50 per cent of the stalks. Counts of the leaning and down stalks made immediately following the storm showed stalks from the horny group to be slightly more storm resistant.

The rows from horny seed ears also were superior in yield to those from the starchy ones. After making corrections to eliminate errors introduced by differences in stand, the starchy ears still produced 14 per cent less corn than the horny ears. These data furnish direct evidence of the correlation of resistance to root rots in corn plants of dent varieties with a horny character of endosperm and of the susceptibility of those with a starchy endosperm.

## SUMMARY.

Ears of seed corn of dent varieties characterized by starchiness of endosperm have been found to be infected with root-rot organisms more frequently than seed ears characterized by horny endosperm in the same seed lots.

Starchy ears of corn of dent varieties produce larger numbers of weaker growing plants, more susceptible to root rots in the field, than do ears more horny in composition.

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